Chapter 2

A Holistic Conceptual Scheme for Sustainable Building Design in the Context of Environmental, Economic and Social Dimensions

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Additional information is available at the end of the chapter

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Abstract

Sustainable building design concept, which has emerged in the construction sector in recent years, has appeared as a response to environmental pollution caused by the construction sector. In the context of sustainable building design, it is intended to create built environment sensitive to environmental, economic, and social problems. Within the scope of this study, sustainable building design is contextualized by a holistic conceptual scheme considering aspects, strategies, criteria, and procedures of creating an environmental, economic, and social awareness by taking into account how to design sustainable buildings. According to the suggested scheme, strategies of environmentally sustainable building design aspect are classified as site efficiency, water efficiency, energy efficiency, and material efficiency; strategies of economically sustainable building design aspect are classified as resource efficiency and cost efficiency; and strategies of socially sustainable building design are classified as health and well-being and public awareness. Furthermore, related criteria for each strategy and related procedures for each criterion are determined. This scheme is intended to indicate the responsibilities of the construction sector in the context of environmental, economic, and social sustainability and to guide the actors of the construction sector and the researchers in this sense.

Keywords: construction sector, sustainable building design, environmentally sustainable design, economically sustainable design, socially sustainable design

1. Introduction

Environmental pollution that occurred as a consequence of industrial development, population growth, and urbanization is one of the extremely important problems of our day. Seventeen percent of water sources, 25% of forestry products, and 40% of energy sources are consumed by the construction sector [1–3]. For this reason, sustainable building design concept has emerged in the construction sector in recent years. The aim of sustainable building design is to create a built environment that does not disrupt the ecological balance, minimizes the harmful impacts of buildings on the environment, uses resources economically, and provides the necessary conditions for human comfort and health [4]. In this context, sustainable building design can be examined under environmental, economic, and social aspects. The effective use of the site, water, energy, and materials should be taken into consideration during the building design process within the scope of environmentally sustainable building design. Economic constraints in the construction sector have to be determined by using resources effectively and performing cost-effective analyses in the context of economically sustainable building design. Besides, health and well-being of users ought to be enhanced, and public awareness should be provided in the sense of socially sustainable building design.

In accordance with the abovementioned issues, a holistic conceptual scheme is suggested by considering aspects, strategies, criteria, and procedures in this study. According to the suggested scheme, strategies of environmentally sustainable building design aspect are classified as site efficiency, water efficiency, energy efficiency, and material efficiency; strategies of economically sustainable building design aspect are classified as resource efficiency and cost efficiency, and strategies of socially sustainable building design are classified as health and well-being and public awareness. Furthermore, related criteria for each strategy and related procedures for each criterion are determined. By this means, it is intended to create awareness among the actors of the construction sector and the researchers in terms of sustainable building design in this study. Within the scope of this intention, the aim of this study is to present a guiding scheme by considering aspects, strategies, criteria, and procedures of creating an environmental, economic, and social awareness at the local and the global level.

2. Aspects of sustainable building design

Costs of energy and natural resources used by the buildings in the construction, usage, and demolition processes are remarkably high [5]. For a more habitable and economic future, sustainable building design procedures have been developed in the world which use land efficiently, use energy effectively, experience projects to reduce water consumption, and give importance to the material efficiency and indoor air quality considering the waste problem and environmental problems [6]. Sustainable building design offers minimum operational cost for the buildings by minimizing the energy consumption, resource usage, and environmental impacts of the buildings [7]. In this context, buildings are evaluated within the framework of international building certification systems that contribute to minimizing the environmental impacts of the buildings and lead the way to the designers, and they are certificated according to sustainability classifications. The most widely accepted and commonly used building certification systems in the world can be stated as Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED).

BREEAM is the first sustainability assessment method for master planning projects, infrastructure, and buildings. It addresses a number of lifecycle stages such as new construction, refurbishment, and in use. BREEAM guides designers, researchers, and related actors to excel, innovate, and make effective use of resources. According to the BREEAM system developed by the Building Research Establishment (BRE), buildings become entitled to obtain pass, good, very good, excellent, and outstanding certificates. Globally in 76 countries, there are 562,455 BREEAM certified developments and almost 2,266,120 buildings registered for assessment as of November 2017, since it was first launched in 1990 [8].

LEED is a system, which identifies buildings as healthier, more environmentalist, and more economical than traditional buildings, for certifying high-performance buildings and sustainable neighborhoods [9]. LEED provides a framework to create healthy, highly efficient, and cost-saving green buildings available for all building types. LEED reveals sustainable design, construction, and operating criteria in building and urban scale. According to the LEED system developed by the US Green Building Council (USGBC), buildings become entitled to obtain platinum, gold, silver, and certificated certificates. Globally in more than 165 countries and territories, more than 2.2 million square feet built-up area is LEED certified, with more than 90,000 projects using LEED as of November 2017, since it was first launched in 1998 [10].

It is often observed that only the environmental aspect of sustainability is directly taken into account when green building certification systems are examined. However, in the design of sustainable buildings, the economic aspect that produces a long-term positive economic impact and the social aspect that improves the lives of those with whom the buildings interact need to be absolutely included in the design [9]. In this study, aspects, strategies, criteria, and procedures of sustainable building design are classified considering the conceptual frameworks of different scientific studies [4, 6, 11–17] and the LEED [10] and BREEAM [8] evaluation criteria. This classification is presented in **Table 1**.

Sustainable building design aspects can be achieved by certain criteria and procedures in design, construction, usage, and demolition processes of buildings by meeting the strategies of site efficiency, water efficiency, energy efficiency, and material efficiency in terms of *environmentally sustainable building design*; the strategies of resource efficiency and cost efficiency in terms of *economically sustainable building design*; and the strategies of health and well-being and public awareness in terms of *socially sustainable building design*.

2.1. Environmental aspect of sustainable building design

Environmental sustainability means leaving the world's future generation something better than what has been left to, protecting environmental balance and natural systems from destruction [18]. Nowadays, as environmental problems become more and more significant,

Sustainable building design scheme			
Aspects	**Strategies**	**Criteria**	**Procedures**
Environmentally sustainable building design	Site efficiency	Protection of natural habitats	See **Table 2**
		Protection of natural topography	
		Protection of fertile lands	
		Improvement of urban areas	
		Improvement of transportation systems	
		Reduction of heat island effect	
	Water efficiency	Reduction of water consumption	See **Table 3**
		Reuse of waste water	
		Unpolluted use of water resources	
	Energy efficiency	The use of passive heating, ventilating, and air conditioning	See **Table 4**
		The use of active heating, ventilating, and air conditioning	
		Utilization of daylighting	
	Material efficiency	Reduction of environmental impacts	See **Table 5**
		Reduction of wastes	
		Proper sizing of building and systems	
Economically sustainable building design	Resource efficiency	Conservation of raw materials	See **Table 6**
		Reduction of the use of nonrenewable resources	
	Cost efficiency	Reduction of initial cost	See **Table 7**
		Reduction of operating cost	
		Reduction of recovery cost	
		Satisfaction of the construction sector actors	
Socially sustainable building design	Health and well-being	Creation of livable environments	See **Table 8**
		Creation of appropriate indoor comfort conditions	
	Public awareness	Educating the public	See **Table 9**
		Development of incentives and policies	

Table 1. A holistic conceptual scheme for sustainable building design.

there has been an inclination for an environmentally sustainable building design to reduce these problems. In order to ensure that the buildings have environmentally sustainable characteristics, procedures are adjusted based on the strategies of site, water, energy, and material efficiency. Demand for the site, water, energy, and material increases the impact of construction sector on the environment. The local and global environments are affected by interrelated user activities and natural processes throughout the existence of buildings, and buildings impose a long lasting impact on the environment [19, 20]. In this context, the construction sector is responsible for producing sustainable environments via designing sustainable buildings. Sustainable building design includes the building materials that are sensitive to the environment; that are reusable and renewable; that minimize energy consumption; that use renewable and local sources by reducing the use of natural resources; that create healthy indoor areas; that use solar power, natural ventilation, and daylighting; and that do not require frequent maintenance and repair [21]. The emphasis for buildings should be placed on effective usage of the site, water, energy, and material within the context of environmentally sustainable building design. In this context, environmentally sustainable building design strategies can be classified as *site efficiency*, *water efficiency*, *energy efficiency*, and *material efficiency*.

2.1.1. Criteria and procedures for strategy of site efficiency

Land, which is one of the limited sources, has been decreasing due to urban expansion. For this reason, it is essential that lands must be used efficiently. The strategy of site efficiency consists of sustainable land use, habitat protection, and improvement of long-term biodiversity for the building site and surrounding land. It addresses the environment surrounding the building and emphasizes the relationships among buildings and ecosystems. In this context, the criteria for the strategy of site efficiency are classified as *protection of natural habitats*, *protection of natural topography*, *protection of fertile lands*, *improvement of urban areas*, *improvement of transportation systems*, and *mitigation of heat island effect* in this study. Additionally, related procedures for each criterion are determined and presented in **Table 2**.

Protection of natural habitats: Soil erosion, groundwater contamination, acid rain, and other industrial pollutants are damaging the health of plant communities, thereby intensifying the challenge and necessity to restore habitats [16]. For this reason, in sustainable building design, solutions should be produced to preserve the existing natural resources, flora, and fauna, and measures must be taken to ensure that the wastes are disposed of without harming the natural habitat. It ought to be attempted to improve natural habitats through appropriate planting and water use and avoidance of chemicals as much as possible in the design of sustainable buildings. Local wildlife and vegetation should be recognized as part of the building site [19]. Furthermore, wetlands and other wildlife habitats may require protection and limit the buildable area of a site [22].

Protection of natural topography: Topography refers to the configuration of surface features of a plot of land, which influences where and how to build and develop a site. A building has to be constructed in compliance with topography, with minimum disturbance of existing land forms and natural drainage patterns while taking advantage of natural ground slopes and the microclimate of the site. In addition, the amount of cut and fill area required for construction of a foundation and site development should be equalized [22]. The existing contours of a site ought to be respected. Alteration of contours affects how wind moves through a site and how water drains [20]. The drainage of surface water and ground water must be taken into account when modifying land forms, and water table has to be preserved [22]. A building

Strategy of site efficiency	
Criteria	**Procedures**
Protection of natural habitats	Preservation of existing natural resources
	Preservation of existing flora and fauna
	Disposal of wastes without harming the habitat
Protection of natural topography	Construction of the building in compliance with topography
	Preservation of water table
	Disposal of wastes without harming the topography
Protection of fertile lands	Prevention of misuse of agricultural lands
	Reduction of erosion and industrial pollutants
	Disuse of toxic pesticides
	Improvement of agricultural lands lost due to misuse
	Prevention of agricultural lands from being made available as settlement
	Carrying off fertile lands of the construction site to green areas
	Disposal of wastes without causing land pollution
Improvement of urban areas	Selection of location according to urban density
	Increase in green areas
	Promotion of mixed-use urban development
	Effective use of construction sites
	Redevelopment of brownfields
	Reclamation of abandoned mine lands
	Rehabilitation of existing settlements and buildings
Improvement of transportation systems	Development of pedestrian/bicycle transportation systems
	Extension of public transport network
	Integration of building design with public transportation
	Development of public transportation from regional parking lots to city centers
	Improvement of rail transport systems in urban areas
	Provision of human-powered public transportation
	More common use of clean fuels in transportation
	More common use of vehicles with less fuel consumption
	More common use of smart traffic practices and systems
	Rise of efficiency standards in vehicles
	Creation of pedestrian ways, pockets, and lanes
	Creation of parking systems and local parking lots
Mitigation of heat island effect	Preservation of existing tree cover
	Increase of forest areas
	Selection of right vegetation for right places around buildings
	Integration of green areas in building design
	Application of green wall systems
	Application of green roof systems

Table 2. Criteria and procedures for strategy of site efficiency.

design should not need excavation below the water table and should not be constructed into the water table [19]. Moreover, it is essential that the wastes are being disposed of without harming the natural topography.

Protection of fertile lands: Fertile lands are the basis for agricultural production, and protection of fertile lands is an extremely important matter for the economy of all countries [23]. Twenty-five percent of fertile lands have been lost or degraded in the last 50 years. Fertile lands are limited because of soil, wind and water erosion, raw material extraction, groundwater contamination, water logging, acid rain, soil nutrient mining, industrial pollutants, and toxic pesticides [24]. It is a well-known fact that it takes a long time for the infertile lands to self-reclaim, and the costs of land reclamation are so high. For this reason, some solutions should be produced to prevent misuse of agricultural lands, and some precautions must be taken to improve agricultural land lost due to misuse [25]. Lands are important not only for the agricultural sector but also for the construction sector in building scale and urban scale. In urban areas, agricultural lands should be prevented from becoming available as settlements. However, if needed, fertile lands of the construction site ought to be carried to other green areas. Additionally, the wastes from the structure and infrastructure need to be removed from the land without causing pollution.

Improvement of urban areas: The spatial growth affects urban areas in terms of increased traffic, pollution, and energy consumption. Appropriate planning of urban areas can help to reduce urban sprawl, soil sealing, and biodiversity loss [26]. The scope of the planning is to locate the settlements and green areas according to urban density. These measures have to also promote mixed-use development (the mixing of residential, commercial, office, and retail spaces) that will reduce transport demand and in turn reduce pollution [27]. Moreover, appropriate planning decisions for construction sites can minimize invasion of heavy equipment and the accompanying ecosystem damage. Excavations in the construction site should not alter the flow of groundwater, and vegetation should only be removed when absolutely necessary for access [20]. It is also essential that lower environmental quality, idle or underutilized areas such as brownfields and abandoned mine lands, and empty buildings ought to be improved. Redevelopment and reclamation of these lands can provide a range of environmental, economic, and social benefits [28]. Furthermore, lands can be conserved by adopting a policy of zero expansion of existing urban areas. This could be achieved by adaptive the reuse of existing settlements and buildings, thereby eliminating the need for new construction [16].

Improvement of transportation systems: As the natural and economic resources are limited, sustainable development of the transportation systems in urban areas is extremely important in order to maintain future quality of life [29]. Transportation systems are an indispensable element of sustainable development due to the environmental, economic, and social impacts. Establishing a sustainable transportation system requires a comprehensive and integrated approach to policymaking and decision-making, with the aim of developing affordable, accessible, economically viable, low carbon, comfortable, people-oriented, and environment-friendly systems [30]. For all these elements to be achieved, it is necessary to integrate the procedures such as improving and expanding pedestrian and bicycle transportation systems, extending public transport network, integrating building design with public transportation, better connection with public transportation to city centers from regional parking lots, improving the attraction of public transportation [31], and enhancing rail transportation systems in urban areas. Besides these, human-powered public transportation systems, less fuel-consuming vehicles, clean fuels in transportation, smart traffic practices, and systems ought to be more widely used to reduce urban air pollution, to tackle climate change, and to contribute limiting the use of private cars. Efficiency standards for environmental performance of vehicles and comfort of users should be also improved [32], and technological solutions have to be developed aiming to reduce the negative impact per car and per kilometer [33]. Moreover, pedestrian zones and parking systems should be developed, and local parking lots ought to be increased in order to encourage nonmotorized modes, to limit the number of vehicles in the city centers, and to reduce the traffic congestion.

Reduction of heat island effect: Heat island is the most documented phenomenon of climate change [34]. A building's roof, façade, and site area influence the heat gain and retention of a building's surroundings [35] and can cause heat island effect. As a result of heat island effect, high temperatures occur in urban areas. High temperatures affect health, economy, leisure activities, and well-being of users and may also enhance air pollution, for example, by increasing surface ozone concentration with several negative impacts on human health [36]. In order to reduce heat island effect, existing tree cover should be preserved, and forest areas should be increased principally. Additionally, trees and plants help to cool the environment, making vegetation an effective way to reduce heat island effect. Planting right vegetation for right places around buildings can contribute to lower surface and air temperatures by providing shade and evapotranspiration [37]. Deciduous trees planted in the south of a building ensure solar heat gain in winter and shade in summer. Coniferous trees planted on the north protect the building from wind in winter and provide shade in summer. Integration of green areas in building design may, therefore, be essential for adaptation to and mitigation of thermal impacts of both local and global warming processes [36]. Another essential procedure for mitigation of heat island effect is greening roofs and walls combining nature and buildings. These systems can lower the surface temperatures of roofs and walls and thus can decrease the corresponding sensible heat flux to the atmosphere [34]. Greening walls with vegetation to intercept the radiation can reduce the warming up of walls, especially in dense urban areas. In the urban areas, the impact of evapotranspiration and shading of plants can significantly reduce the amount of heat that would be reradiated by walls [38].

2.1.2. Criteria and procedures for strategy of water efficiency

Water is probably the most important matter in the environment and humankind's life cycle. Protecting clean water resources has a vital importance [39]. The strategy of water efficiency consists of indoor use, outdoor use, specialized uses, and metering in the building site and surrounding land. It addresses all sources of water related to building and surroundings, including appliances, fixtures, fittings, process water, and irrigation. In this context, the criteria for the strategy of water efficiency are classified as *the reduction of water consumption*, *reuse of waste water*, and *unpolluted use of water resources* in this study. Additionally, related procedures for each criterion are determined and presented in **Table 3**.

Reduction of water consumption: Efficient water use is an environmental priority in all countries. Special attention must, therefore, be given to the reduction of water consumption in building

Strategy of water efficiency	
Criteria	**Procedures**
Reduction of water consumption	Use of waterless toilets and urinals
	Use of bio composting toilets
	Use of small volume cisterns
	Use of water-saving flushes
	Use of low-flow fixtures
	Use of timers and automatic control devices
	Use of indigenous landscaping
	Use of vegetation with less water need
	Use of low-maintenance vegetation
Reuse of waste water	Treatment and reuse of graywater
	Treatment and reuse of rainwater
Unpolluted use of water resources	Renovation of sewage systems to prevent contamination of water resources
	Control of polluting elements in sewage and storage areas
	Disposal of wastes without causing pollution in water resources
	Reduction of toxic pesticides
	Management of water resources systems

Table 3. Criteria and procedures for strategy of water efficiency.

design [40]. For this reason, losses through water installations and leakages ought to be minimized. Water-efficient devices such as waterless toilets and urinals, bio composting toilets, small volume cisterns, water-saving flushes, low-flow fixtures, timers, and automatic control devices should be utilized for indoor use. It should be noted that the use of these devices also contributes to the reduction of energy consumption, cost, and waste water. Apart from these, indigenous landscaping for outdoor building design has to be encouraged, which, once established, virtually eliminates the need for watering [41]. In the meanwhile, vegetation with less water and maintenance need to be planted for outdoor use.

Reuse of waste water: As the water resources are limited, providing water efficiency in the building and surroundings is vitally important. The efficient use of water may reduce input and output water resources. This is because the water that is supplied to a building and the water that leaves the building as waste water should be treated. Therefore, a reduction in water use produces a reduction in waste water [42]. Waste water in buildings can be classified as graywater and black water. Graywater means the low polluted wastewater from bathtubs, showers, hand-washing basins, and washing machines excluding wastewater from the kitchen and the toilet flushing system [43]. Graywater might be treated by installing graywater treatment systems in order to flush toilets and to irrigate vegetation except for edible plants. In addition, the reuse of graywater promotes a significant reduction in potable water consumption and sewage production [44]. Blackwater is any waste from toilets or urinals containing disease-causing bacteria and viruses that can result in human illness and must be discharged to the municipal sewage system. Rainwater might be seen as a resource that provides many environmental and economic benefits. Rainwater ought to be treated by installing rainwater treatment systems in order to restore natural hydrologic conditions, to reduce the possibility of flooding, and to irrigate vegetation [35].

Unpolluted use of water resources: As the world's population grows, ensuring reliable access to clean water is becoming increasingly difficult [45]. It is therefore that water resources must not be contaminated. In order to prevent contamination of water resources, existing sewage systems should be rehabilitated, and polluting elements in sewage and storage areas ought to be monitored. In the meantime, wastes have to be disposed without causing pollution, and measures must be taken to reduce toxic pesticides in water resources. In addition to all these, proper planning and managing have to be performed to increase benefits from the existing water resources.

2.1.3. Criteria and procedures for strategy of energy efficiency

Energy requirement increases approximately 5% every year mainly due to industrialization, rapidly growing population, and improvement in the living standards [3]. Ever-increasing consumption of fossil fuel reserves providing the major portion of the energy needs, directly or indirectly, gives rise to the ozone layer depletion, air pollution, and climatic change. In this respect, efficient utilization of energy has become more crucial than ever in construction sector [39, 46]. Strategy of energy efficiency consists of utilization of renewable energy resources for natural heating, ventilating, air conditioning, and illumination. It addresses the use of the passive and active systems in the building and surroundings. In this context, the criteria for the strategy of energy efficiency are classified as the *use of passive heating, ventilating, and air conditioning*; *the use of active heating, ventilating, and air conditioning*; and *utilization of daylight*. Additionally, related procedures for each criterion are determined and presented in **Table 4**.

The use of passive heating, ventilating, and air conditioning: Parts of the major energy consumption in buildings are the heating, ventilating, and air conditioning (HVAC) systems. These systems can be accepted as indoor climate controls that regulate humidity and temperature. With the total amount of HVAC's energy consumption in buildings, they are closely related to the local climatic condition, whether it is necessary to heat the space or cool it. Heating systems are to collect and to store the solar heat and to retain the heat within the building. On the contrary, cooling systems are to provide cold or to protect the building from direct solar radiation and to improve air ventilation. Space heating is the most important building energy user in cold countries, whereas air conditioning is a major contributor to peak electricity demand in hot climate countries or during summer [47]. In this regard, Trombe walls, metal walls, double-skin façades, greenhouses, Venturi chimneys, wind scoops, atriums, building shading devices, cross ventilation, and labyrinth systems ought to be used as passive systems. Aside from these, the use of high-performance windows and wall, ground, ceiling, and roof insulation prevents heat gain or loss and thus reduces energy consumption. In accordance with local climatic conditions, procedures of appropriate building distance, position, form, façade color, location, and building envelope surface must be taken into account in passive building design. Vegetation is also a procedure that affects the building design in terms of heat gain and loss. In this sense, deciduous trees ought to be planted on the south of a building and coniferous trees on the north (see Section 2.1.1), and existing green areas should certainly be preserved.

Strategy of energy efficiency	
Criteria	**Procedures**
Use of passive heating, ventilating, and air conditioning	Use of Trombe walls for natural heating and air conditioning
	Use of metal walls for natural heating and air conditioning
	Use of double-skin façades for natural heating and air conditioning
	Use of greenhouses for natural heating and air conditioning
	Use of Venturi chimneys for natural ventilating
	Use of wind scoops for natural ventilating
	Use of atriums for natural heating and air conditioning
	Use of building shading devices for natural air conditioning
	Use of labyrinth systems for natural heating, ventilating, and air conditioning
	Use of wind energy by cross ventilation method for natural ventilating
	Use of effective insulation systems
	Selection of appropriate distance to other buildings compatible with local climatic conditions
	Selection of appropriate position for building compatible with local climatic conditions
	Selection of appropriate building form compatible with local climatic conditions
	Use of appropriate colors on façades compatible with local climatic conditions
	Determination of building envelope surface compatible with local climatic conditions
	Selection of appropriate location for building
	Selection of right vegetation for right direction around buildings
	Preservation of existing green areas
Use of active heating, ventilating, and air conditioning	Use of photovoltaic panels for power generation
	Use of solar collectors for water heating
	Use of wind turbines for power generation
	Use of water source heat pumps for power generation and water heating
	Use of geothermal heat pumps for power generation and water heating
	Use of energy efficient appliances and equipment with timing devices
Utilization of daylighting	Use of light shelves
	Use of solar tubes
	Use of heliostats
	Use of anidolic ceilings

Table 4. Criteria and procedures for strategy of energy efficiency.

The use of active heating, ventilating, and air conditioning: The main goal for energy conservation is to reduce the consumption of fossil fuels as well as increasing the use of renewable energy resources such as solar, wind, water, and geothermal [16]. This could be achieved by utilizing active heating, ventilating, and air conditioning systems in buildings, which is essential in terms of energy efficiency. In order to maximize energy efficiency, active systems should be integrated with passive systems in building design. Active heating, ventilating, and air conditioning systems, which enable the efficient use of renewable energy sources in buildings, contain mechanic and electronic appliances and equipment. Photovoltaic panels, solar collectors, wind turbines, water source heat pumps, geothermal heat pumps, energy efficient appliances, and equipment with timing devices should be integrated to building design in the scope of active systems. The installation cost of active systems is considered as an additional initial cost of the building. However, these systems ensure a significant decrease in operating costs.

Utilization of daylighting: Typically, one third of the energy used in many buildings is consumed by electric lighting. Therefore, in recent years daylighting has become a major topic in energy efficient building design next to passive solar heating and cooling [48]. Good daylighting design can reduce electricity consumption for lighting; improve standards of visual comfort, health, and amenity for the users [49]; and provide a better indoor light environment than artificial lighting. Artificial lighting not only consumes a large amount of electricity but also dissipates waste heat into indoor space, which causes the increase of cooling loads. If the effective use of daylighting is integrated in building design, the cooling and lighting energy can decrease [48]. Daylighting can be achieved by bringing natural light into buildings with some systems such as light shelves, solar tubes, heliostats, and anidolic ceilings.

2.1.4. Criteria and procedures for strategy of material efficiency

Materials are the fundamental components of a building. Construction sector consumes approximately 3 billion tons of raw materials which comes up to 40% of total usage per year globally [46]. The production and consumption of building materials has diverse impacts on the local and global environments. Extracting, processing, manufacturing, transporting, and recycling building materials cause environmental impacts to some extent [50]. The strategy of material efficiency consists of reducing these impacts through the entire life cycle of building materials from extraction to the end of life, as well as reducing the construction wastes and sizing the building properly. It focuses on procurement of materials that are sourced in a responsible way and have a low embodied impact over their life cycle [8]. In this context, the criteria for the strategy of material efficiency are classified as *reduction of environmental impact*, *reduction of waste*, and *proper sizing of building and systems* in this study. Additionally, related procedures for each criterion are determined and presented in **Table 5**.

Reduction of environmental impacts: Buildings maintain their relationship with the environment throughout their life cycles on local or global scales and cause a number of environmental impacts [51]. In this context, the sustainable construction sector is responsible for designing buildings which do not disturb the balances of ecosystems, which secure human health, welfare, and comfort; which ensure economic use of materials; which encourages conservation of nonrenewable energy resources; which saves transportation energy; and thus which contributes to minimizing environmental impacts. It is essential to use local, natural, high-performance, long-lasting, durable, nontoxic, noncarcinogenic, antibacterial, low embodied energy, and low volatile organic compound (VOC) building materials. Furthermore, the use of building materials made of renewable sources, with less maintenance need, and those extracted without ecological damage are of great importance as well as the use of certified wood materials and reporting tools such as Environmental Product Declarations [52] and Health Product Declarations [53].

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Strategy of material efficiency	
Criteria	**Procedures**
Reduction of environmental impacts	Use of local building materials
	Use of natural building materials
	Use of high-performance building materials
	Use of long-lasting building materials
	Use of durable building materials
	Use of nontoxic and noncarcinogenic building materials
	Use of antibacterial building materials
	Use of low embodied energy building materials
	Use of low volatile organic compound (VOC) building materials
	Use of building materials made from renewable sources
	Use of building materials with less maintenance need
	Use of building materials extracted without ecological damage
	Use of certified wood materials
	Use of environmental and health product declarations
Reduction of wastes	Use of reusable building materials
	Use of recyclable building materials
	Use of reclaimed building materials
	Use of recycled building materials
	Use of nonconventional products as building materials
	Rehabilitation and reuse of existing structures
	Rehabilitation and reuse of existing infrastructures
	Sorting, storage, and disposal of wastes by waste management
Proper sizing of building and systems	Design of sufficient-sized interior spaces
	Reduction of building envelope surface
	Use of simple geometrical forms for building design
	Utilization of flexible and modular building design
	Utilization of standard building material sizes

Table 5. Criteria and procedures for strategy of material efficiency.

Reduction of wastes: The rate of construction sector-based wastes corresponds more than 30% of the total wastes. Within this scope, it is of great importance to target sustainable building design in the construction sector [54]. It should be noted that buildings that are demolished become the resources for new buildings [55]. During the process of building design, it is necessary to select reusable, recyclable, reclaimed, recycled building materials and nonconventional products in order to lower embodied energy of materials; to reduce the need for new landfills; to reduce air, water, and soil pollution; to minimize transportation requirements; to reduce the use of raw materials; and to enable the economic use of materials. On the other hand, rehabilitation and reuse of existing structures and infrastructures instead of brand-new ones are other effective procedures that reduce construction sector-based wastes. Apart from these, waste management of construction and demolition phases in terms of sorting, storage, and disposal of wastes should be implemented.

Proper sizing of building and systems: It is necessary to optimize the building size in order to reduce overall building material use, wastes, embodied energy, energy loads, and costs and to conserve resources. This can be achieved by ensuring functionality between spaces and circulation according to target utilization rates (number of square meters per person or unit), by designing individual spaces to fulfill multiple functions, and by dumping unused spaces [56]. Furthermore, reducing building envelope surface, using simple geometrical mass forms; designing flexible and modular spaces; and utilizing standard commercially available material sizes are the other procedures for proper sizing.

2.2. Economic aspect of sustainable building design

Economic sustainability is defined as the use of various strategies for employing existing resources optimally, so that a responsible and beneficial balance can be achieved over the longer term [57]. Economic sustainability is inextricably linked to both environmental and social sustainability [58]. Sustainable building design does not only improve the quality of environment and comfort of users but also has many economic benefits as well. The initial cost of the building can be higher than a conventional building owing to the innovative use of sustainable building materials, systems, and equipment through integrated sustainable building design process. However, sustainable buildings decrease annual costs in terms of energy, water, maintenance and repair, and other operating costs so that the life cycle cost is lower than the cost of conventional buildings. In addition to the mentioned cost savings, sustainable buildings also provide indirect economic benefits such as increasing comfort and productivity of users, reducing absenteeism, and increasing property value, to both the actors of the construction sector and users [59]. Reducing costs based on construction wastes, pollution, infrastructure, and transportation can also be considered as indirect economic benefits. In this context, economically sustainable building design criteria can be classified as *resource efficiency* and *cost efficiency*.

2.2.1. Criteria and procedures for strategy of resource efficiency

The construction sector is a major consumer of all resources, and therefore the actors of the construction sector have pursued to design sustainable buildings focusing on increasing the efficiency of resource use [16]. Resource efficiency refers to the conservation of raw materials and nonrenewable resources based on life cycle conception to design buildings that consume fewer resources and that leads to less environmental impacts. The strategy of resource efficiency comprises both energy and material efficiency (see Sections 2.1.3 and 2.1.4). Whereas energy efficiency considers the economical use of nonrenewable resources, encouraging the use of renewable resources, material efficiency is about the economical use of raw materials and reduction of wastes. Resource efficiency addresses human impacts on natural resources, economic requirements for land use, environmental impacts, amount of material used, and the ratio of gross domestic product (GDP) to material used [60]. In this context, the criteria for the strategy of resource efficiency are classified as *conservation of raw materials* and *conservation of nonrenewable resources* in this study. Additionally, related procedures for each criterion are determined and presented in **Table 6**.

Strategy of resource efficiency	
Criteria	**Procedures**
Conservation of raw materials	Use of reusable building materials
	Use of recyclable building materials
	Use of reclaimed building materials
	Use of recycled building materials
	Use of long-lasting building materials
	Rehabilitation and reuse of existing structures and infrastructures
	Development of new eco-innovative building materials
	Optimization of supply chain
	Optimization of material production techniques
Conservation of nonrenewable resources	Increase of use of renewable energy resources
	Reduction of energy consumption in all life cycle stages of buildings
	Use of energy saving electrical installation
	Use of energy saving heating, ventilating, and air conditioning installation

Table 6. Criteria and procedures for strategy of resource efficiency.

Conservation of raw materials: Conservation of resources means achieving more with less [16]. Nowadays, certain resources are becoming extremely rare; that's why the use of remaining stocks should be treated cautiously [61]. The scarcity of raw material stocks results in a threat for the economy. The extraction of raw materials may damage lands; the production, usage, and disposal of materials can have significant environmental impacts; and these processes may be energy intensive, labor intensive, and very costly [60]. In this context, resource efficiency ought to be handled based on life cycle assessment (LCA) methodology, as depletion of abiotic resources is one of the prominent environmental impact indicators of this methodology [62]. Raw materials, which are assigned as abiotic resources, can be conserved by using secondary materials such as reusable, recyclable, reclaimed, recycled building materials. Construction wastes can be also reduced by this way. Improving durability, service life, the technical and economic performance of building materials, reusing existing structures and infrastructures, and developing new eco-innovative building materials are other procedures of conservation of raw materials. Additionally, supply chain and material production techniques should be optimized in order to convert raw materials into final building products with less environmental impacts [63].

Conservation of nonrenewable resources: Energy use in buildings from life cycle perspective is one of the significant economic issues, as buildings are intensive energy consumers. Buildings consume energy at each stage of their life cycles, from cradle to grave. The energy consumed in usage stage of buildings accounts for a considerable part of the total energy. For this reason, minimizing the use of energy in usage stage is a central task in sustainable building [64]. Energy use in usage stage of the buildings includes both operational and embodied energy [65]. Operational energy comes out as a result of heating, ventilating, air conditioning, and hot water use in buildings, while the embodied energy occurs from the choice of building materials used.

Nowadays, energy used in buildings for electricity is supplied from nonrenewable resources, which are fossil fuels such as natural gas, fuel oil, and coal. The reserves of these resources are limited reserves. The entire world, therefore, looks for the means of safe and continuous access to energy [66]. In this sense, using renewable energy resources, reducing the energy consumption of in all life cycle stages of buildings, and using energy saving electrical, heating, ventilating, and air conditioning installations are important tasks to take into consideration.

2.2.2. Criteria and procedures for strategy of cost efficiency

The construction sector can be mentioned as the sector of the economy which plans, designs, constructs, alters, refurbishes, maintains, repairs, and eventually demolishes buildings. The inputs of the sector are obtained from other sectors of the economy, such as manufacturing, financial services, local government, commercial sectors, and industrial sectors supplying materials. Due to these dealings, there have been considerable procedural and structural changes in the construction sector, such as the increased use of design and construct arrangements, integrated project management processes, novation, partnering, benchmarking, re-engineering, management contracting, private finance initiatives, and public and private partnerships. Concordantly, life cycle cost management of building projects has become progressively important in terms of delivering the highest-quality projects in time with accurate budgeting and cost control, ensuring cost efficiency [67]. Through life cycle cost perspective, there are three main costs to be considered at the outset of a building project, being the initial building investment cost, the cost of the building in use, and the cost of building recovery [68]. In this respect, the strategy of cost efficiency focuses on long-term economic performance with minimized initial, operating, and recovery costs providing satisfaction of the actors of the construction sector. The criteria for the strategy of cost efficiency are classified as the *reduction of initial cost*, *reduction of operating cost, reduction of recovery cost*, and *satisfaction of the construction sector actors* in this study. Additionally, related procedures for each criterion are determined and presented in **Table 7**.

Reduction of initial cost: The initial cost, also referred to as acquisition cost or development cost, covers the entire cost of designing and constructing a building. In a broad sense, initial cost comprises land and building acquisition costs, professional consultant fees, the cost of the building materials, and the cost of construction processes. It can be said that the initial cost is the basic and sometimes the only source of concern for many actors in the construction sector [68]. Therefore, initial cost reduction procedures should be considered in sustainable building design process. Recycled, reclaimed, and locally available building materials have to be selected to reduce the cost value of materials and transportation costs. Deconstruction techniques rather than demolition have to be employed to reclaim materials for reuse in other applications on site [69]. Flexible and modular designs and standardized building components, which allow reconfiguration when required, must be preferred [70]. Common and readily available building components should be selected to minimize replacement costs and to reduce stocking of components. Building components that cannot be easily repaired or replaced ought to be selected as durable to minimize replacement and retrofitting [16]. Appropriate storage facilities should be provided on site to maintain the integrity of the materials [69]. Cost saving and proper construction technologies must be implemented for different types of buildings.

Strategy of cost efficiency	
Criteria	**Procedures**
Reduction of initial cost	Use of local building materials to reduce transportation cost
	Use of recycled building materials
	Use of reclaimed building materials
	Reduction of transportation to and from the site
	Utilization of flexible and modular building design
	Use of standardized building components
	Use of common and available building components
	Safe and correct storage of building materials
	Reduction of time for assembly of building materials on site
	Selection of appropriate construction technologies for various building types
	Selection of appropriate suppliers for building materials
	Selection of right labor force for right positions
Reduction of operating cost	Selection of long lasting building materials and components
	Reduction of maintenance and repair cost
	Reduction of regular cleaning cost
	Selection of right location for heating, ventilating, and air conditioning systems
	Use of easy-to-use building automation and control systems
Reduction of recovery cost	Consideration of recycling potential of building materials in design phase
	Consideration of reclaiming potential of building materials in design phase
	Reuse of building materials or components
	Consideration of ease of demolition of building in the design phase
	Reuse of an existing building
Satisfaction of the construction sector actors	Improvement of productivity
	Increase of profitability
	Development of lower-cost projects by increasing cost estimation
	Shortening the completion time of the project

Table 7. Criteria and procedures for strategy of cost efficiency.

Besides these, the right workers for the right works and the right supplier choice are the other issues that need to be carefully considered in order to reduce the initial costs.

Reduction of operating cost: The operating cost, also known as the cost in use or the running cost, is affected by the decisions made during the design and construction phases of the building design process in terms of the choice of materials and the impeccability of the detailing [68]. It involves the costs of heating, ventilating, air conditioning services, building automation and control systems, maintenance and repair, and cleaning fees in the usage stage of the building's life cycle. Only the initial cost was estimated, and operating cost was neglected in the design phase before the life cycle cost methodology has underlined the relationship between design decisions and costs in use [68, 71]. In fact, the lower the life cycle cost, the more economically efficient the building [72]. Therefore, implementing operating cost reduction procedures would contribute reducing the life cycle cost of the buildings. Durable, long-lasting, low-maintenance building materials and components have to be preferred to reduce maintenance and repair costs [73]. The access points of central and major elements of heating, ventilating, and air conditioning systems ought to be located properly for easy maintenance, repair, and cleaning. Simple environmental automation and control systems should be selected, as opposed to complex systems with high maintenance costs [74]. If the required efficiency can be achieved by a simple system, then a complicated one ought to be avoided [16].

Reduction of recovery cost: The recovery cost, which consists of the cost of building demolition and materials recovery, is rarely considered by the actors of the construction sector due to looking for short-term gain with minimum outlay [68]. However, recovery cost is also of great importance from standpoint of the life cycle cost methodology. Therefore, implementing recovery cost reduction procedures would promote reduction of the life cycle cost of the buildings. Recycling and reclaiming potential of building materials have to be evaluated in the design phase in order to provide for maximum recovery of materials by reusing them. Besides, proper demolition techniques of the building should be considered and improved through the design phase. Another procedure for reducing recovery cost is reuse of an existing building to reduce the amounts of construction waste, raw materials, and the energy used for material production processes. When all of these are succeeded within the scope of end-of-life perspective, the allocation of resources at minimal costs would be provided, and the value of the building would be increased [75].

Satisfaction of the construction sector actors: The construction sector involves actors such as designers, users, contractors, stakeholders, suppliers, manufacturers, and several organizational levels that have different tasks. These actors make the construction sector a multilevel entity. Satisfaction of the construction sector actors can be stated as an essential criterion of the future economic success of the sector [76]. Long-term economic performance of buildings can be provided with the satisfaction of the actors by improving the productivity of labor force and enhancing profitability. Profitability could be increased by improving the management of the building project process. Meanwhile, accuracy of cost estimation is of great importance in terms of decreasing the costs of the projects. In addition, flows of information, money, goods, and services move between the construction sector actors during the project process [76]. The longer the project process, the greater the costs. In order to decrease the costs during this process, it is necessary to shorten the completion time of the project.

2.3. Social aspect of sustainable building design

Debates about sustainability do not consider sustainability solely as an environmental and economic concern but also incorporate social dimensions [77]. In this respect, the main goals of sustainable development are defined as environmental stewardship, economic prosperity, and social responsibility. These three goals should be interrelated and supportive of each other in order to execute sustainability strategies [78]. When the construction sector is examined, it is observed that the social aspect of sustainability is usually neglected, despite the anthropocentric focus of sustainability definitions [77]. In the mentioned definitions, sustainability focuses on well-being rather than well-having by sustainable livelihoods and addresses fundamental issues for humanity now and in the future, which constitutes the social aspect of sustainable building design [79]. In order to achieve socially sustainable building design, creating unpolluted and safe environments, protecting human health, improving user productivity, enhancing human comfort conditions, creating esthetically satisfactory indoor and outdoor environments, conserving local heritage and culture, improving communication with the public, and developing regulations are of great importance. In this context, socially sustainable building design criteria can be classified as *health and well-being* and *public awareness*.

2.3.1. Criteria and procedures for strategy of health and well-being

It is imperative to pay attention to enhance the quality of life in buildings that encourage a healthy and safe internal and external built environment for users [8] without exhausting natural resources or causing severe ecological damage. The strategy of health and well-being consists of building design procedures ensuring unpolluted, fire- and natural-hazard-resistant, disabled-friendly environments and good indoor environmental quality to protect the health and comfort of building users. It also addresses increased comfort, health, and safety of building users, visitors, and others within the vicinity. Livable and high-quality indoor environments contribute increasing property value, to improve productivity and to reduce absenteeism [80]. In this context, the criteria for the strategy of health and well-being are classified as the *creation of livable environments* and *creation of appropriate indoor comfort conditions* in this study. Additionally, related procedures for each criterion are determined and presented in **Table 8**.

Creation of livable environments: The concept of livability is directly related to the quality of human life. Livability evolves out of a wealth of existing resources and conditions that promote healthy living like clean air, water, and soil. The provision of healthy and comfortable indoor and outdoor spaces is the key indicators of livability, which is related to the effects of building performance on the quality of living. The environmental aspects typically include the issues of noise, visual, air, water, and soil, which cause significant implications on health and well-being of users [81]. For this reason, solutions have to be produced to prevent above-mentioned pollution in order to create livable environments. Additionally, fire protection is essential for livable environments, and fire safety systems have to be advanced. These systems, such as fire sprinklers, can offer environmental benefits by reducing air and water pollution levels and by lowering water usage and fire damage. The resistance to natural hazards should also be ensured. It is not possible to prevent these hazards, but mitigation measures ought to be taken to overcome. Accessibility of disabled users has to be considered, and accessibility features should be improved to make the environment more livable for them [82]. In addition to all these, preservation of cultural heritage and values is another significant procedure of the related criteria.

Creation of appropriate indoor comfort conditions: In developed countries, people spend more than 90% of their time indoors. Indoor conditions have therefore far-reaching implications for their health, general well-being, and performance [83]. Indoor environmental quality of building has a high-level impact on users' health, comfort, and productivity [84]. Apart from these

Strategy of health and well-being	
Criteria	**Procedures**
Creation of livable environments	Prevention of noise pollution
	Prevention of visual pollution
	Prevention of air pollution
	Prevention of water pollution
	Prevention of soil pollution
	Provision of fire protection
	Provision of resistance to natural hazards
	Consideration of the accessibility of disabled users
	Conservation of local heritage and culture
Creation of appropriate indoor comfort conditions	Provision of sufficient indoor air quality
	Provision of appropriate indoor humidity ratio
	Provision of indoor visual comfort conditions
	Creation of visual connection with the outer environment
	Provision of indoor thermal comfort conditions
	Provision of indoor acoustical comfort conditions
	Provision of operable windows
	Provision of clean fresh air
	Use of low volatile organic compound (VOC) building materials
	Prevention of electromagnetic pollution
	Use of nontoxic and noncarcinogenic building materials
	Use of antibacterial building materials

Table 8. Criteria and procedures for strategy of health and well-being.

features, a sustainable building has appropriate ventilation and moisture control, maximizes daylighting to provide indoor visual comfort conditions, creates visual connection with the outer environment, provides indoor thermal comfort conditions, optimizes acoustic performance, provides operable windows and fresh air, and avoids the use of materials with high-VOC emissions [56]. Except these, electromagnetic pollution has to be prevented to improve the indoor air quality, and nontoxic, noncarcinogenic, and antibacterial building materials have to be used for maximizing the comfort of users.

2.3.2. Criteria and procedures for strategy of public awareness

Ensuring sustainability in construction sector depends not only on achieving environmental and economic aspects of sustainability but also the participation of the public and an understanding of the consequences of individual behaviors. Although sustainable building design is envisaged as a necessity in construction sector, in general it continues not to receive much attention between public [85]. As a matter of fact, there is a need to create greater public awareness of the health impacts of buildings, to increase the focus on sustainability strategies, and to encourage building codes to place increased emphasis on healthier building practices [86]. Strategy of public awareness comprises raising consciousness of public and the actors of the construction sector about the benefits of sustainable buildings, mobilization of sustainable building tools, adoption of procedures for sustainable building management, and development of innovative concepts and services [87]. It focuses on developing financial incentives, improving cooperation between organizations, and developing policies for innovative initiatives and technologies on sustainable design features [88]. In this context, the criteria for the strategy of public awareness are classified as *educating the public* and *development of incentives and policies* in this study. Additionally, related procedures for each criterion are determined and presented in **Table 9**.

Educating the public: Creating public awareness about sustainable buildings could be achieved by educating the public. More symposiums, conferences, educational videos, programs, workshops, seminars, and professional talks have to be held under the theme of sustainable buildings in order to educate the public about the importance of sustainability and to raise the awareness. Competitions on sustainable buildings should be organized to improve ability and know-how of the actors of the construction sector that have been gained from their previous experiences [89]. Additionally, media ought to be used intensely and effectively in creating public awareness and improved understanding of issues [90], and public authorities ought to disseminate plans, programs, and other related relevant materials through media [91]. Apart from these, pilot sustainable buildings can be opened to the public for on-site training. Consequently, the public has to be completely environmental conscious and should be encouraged to prefer sustainable buildings.

Development of incentives and policies: It is very crucial to develop policies and approaches that enable utilization of domestic resources complying with the conditions of the countries and

Strategy of public awareness	
Criteria	**Procedures**
Educating the public	Organization of congresses and conventions on sustainable building design
	Implementation of training programs about sustainable building design
	Preparation of educational videos about sustainable building design
	Organization of competitions on sustainable buildings
	Efficient use of media about sustainable building design
	Educating the public in pilot sustainable buildings
Development of incentives and policies	Provision of financial incentives such as tax and customs' duty exemption
	Improvement of cooperation between public and private organizations
	Implementation of policies for the efficient use of renewable energy technologies
	Implementation of the decisions made in the international meetings on environment

Table 9. Criteria and procedures for strategy of public awareness.

to monitor studies pertaining to energy in the world [66]. Sustainable building design and practices can be only achieved by political decision-making, including several incentives and policies based upon public awareness in this manner [92]. Financial incentives such as taxes, subsidies, tradable permits, and rewards do not usually require as much enforcement as regulations [93], whereas it is a considerable procedure for encouraging the actors of the construction sector to opt for sustainable building design. Furthermore, it can be stated that improving cooperation among public bodies, universities, private enterprises, and nongovernmental organizations can support the generalization of sustainable buildings. Finally, policies for efficient use of renewable energy technologies have to be implemented, wide range of innovative policy instruments ought to be developed, and the decisions made in the international meetings on environment must be complied with.

3. Conclusion

Today's world is facing environmental, economic, and social problems. Many studies and researches in various sectors are being carried out to reduce these problems. Sustainable building design can be considered as a path of minimizing environmental, economic, and social problems in the construction sector. In this context, sustainable building design has to be contextualized properly. When reviewing the most recent interpretations of sustainable building design in the literature, many uncertainties and constraints have been observed because of the inability to integrate the environmental, economic, and social aspects of sustainability. These uncertainties and constraints are tried to be solved in this study by developing a holistic conceptual scheme, which comprehensively contextualizes all the strategies, criteria, and procedures associated with the aspects of environmentally, economically, and socially sustainable building design. By this way, it is envisaged that this study can contribute to the improving literature on sustainable building design in terms of site efficiency, water efficiency, energy efficiency, material efficiency, resource efficiency, cost efficiency, health and well-being, and public awareness. Consequently, this scheme may be adopted as a guideline for the actors of the construction sector and the researchers and can help in promoting sustainable building practices in the construction sector. Furthermore, it is of vital significance to develop new laws and regulations, to improve government incentives, to study on new standards, to carry out scientific researches, and to conduct effective training programs.

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